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ADP010418 thru ADP010432

AIRCRAFT DESIGN TO OPERATIONAL COST

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COMPANY BACKGROUND

Aerospatiale Matra Airbus is a subsidiary of the Aerospatiale Matra group which was created in 1999 from the merge between Aerospatiale and Matra Hautes Technologies. Aerospatiale Matra Airbus is involved in the design, production and support of Airbus products within Airbus Industrie.

Airbus Industrie is a European consortium of industries from four different European nations: Aerospatiale Matra Airbus from France , DaimlerChrysler Aerospace Airbus from Germany, British Aerospace from Great Britain and CASA from Spain.

Airbus Industrie is involved in other partnership within Europe for the development of a military transport aircraft.

INTRODUCTION

The method that will be presented to you is used on Airbus products.

The aim of this presentation is to give you an overview and some indications on the process and the associated tools that we have developped to ensure that the design of our products is coherent with the operators expectations in term of operational costs.

The presentation will first show the evolution of the market and of the operators expectations that drove the emergence of the Integrated Logistic Support concept. This will be followed by a description of how we have adapted this concept in a very pragmatic procedure applicable to military transport as well as commercial aircraft design. The five steps of the procedure will then be detailed. An overview of the existing tools and of the environment in which this procedure is applied will follow.

OPERATORS EXPECTATIONS AND ILS CONCEPT

The basic operators objectives when they choose an aircraft are to transport a specified number of passengers or materials loads (CAPACITY) on defined routes (RANGE) with a minimum acceptable level of availability of the aircraft (MISSION & DISPATCH RELIABILITY). The aircraft must be certified with an expected level of SAFETY. It should provide a high PASSENGER COMFORT, produced low emissions and noise (ENVIRONMENTAL IMPACT) and have a low FUEL CONSUMPTION. The evolution of the market toward a very concurrential situation between the operators have brought an additional very important requirement from the operators for low OPERATIONAL COSTS. This is a major issue in their financial success and the aircraft itself is driving a large portion of these costs. Direct Operating Costs (DOC) is thus a major criteria for operators in their purchasing decision.

Direct Operating Costs (DOC) are those expenses supported by the operators directly for the operations of the aircraft. They exclude indirect expenses such as facilities amortization and indirect administrative personal. They include the following costs:
- Acquisition & financial costs related to the purchase of the aircraft, engine, spares initial provisioning and specific maintenance tools.
- Maintenance costs related to direct labor and materials expenses induced by scheduled and unscheduled maintenance activities whatever the location they are performed (line, base, shop or contractor). It also includes the indirect burden induced by maintenance activities, such as management, planning, storage, engineering, energy and customs.
- Insurance costs related to aircraft, spares and tools.
- Fuel expenses required to operate the aircraft.
- Crew wages (technical and cabin crew).
- Landing and navigation charges.

Maintenance costs are the portion of DOC where the aircraft manufacturer has one of the greatest potential field for improvement in reducing the DOC. Maintenance cost represents approximately 13 to 18% of the direct operating costs of a commercial aircraft. Maintenance costs induced by an aircraft are highly related to the aircraft design, engine selection, vendor selection and maintenance concept.

Integrated Logistic Support (ILS) is a concept of program management, initially developed for military program. It aims at integrating up front in the development of the aircraft the tasks that will ensure that the final product (the aircraft and its support elements such as spares, technical publications, maintenance, tools, GSE and training) will be optimized in term of operational costs and will fulfill the operators requirements regarding operational reliability and safety. ILS concept is as well formalizing the planning and management tasks for the development of the support elements.
This approach was a clear evolution from the past approach when maintenance and support elements design were considered once the aircraft design was frozen. The final product was not at that time optimized against operational objectives.

The ILS concept was adapted to military transport aircraft and commercial aircraft development. The adaptation of the concept is what we call the "Design to Operational Cost Process". The objective is to provide guidance to the designers in order to ensure that the estimated operational cost induced by the design choices will be within a predetermined target.

DESIGN TO OPERATIONAL COST PROCESS

The Design to Operational Cost Process is split into five steps: The first steps are conducted up front of the design and their results are to provide inputs to the designers (design requirements). The procedure starts with the settlement of a global target operational cost for the aircraft (Step 1) which is broken down to the lowest level required to match the design responsibility breakdown (Step 2). Then design requirements

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should be selected in accordance with the target to be met and transmitted to the designers (Step 3).
The next steps are conducted down stream of the design activities. It starts by a maintainability analysis which is verifying that the choices are in accordance with the target (Step 4). The last step closes the loop in validating the achievement or in modifying the allocation of targets (Step 5).

The presentation that will follow is mainly describing the application of the procedure to a new aircraft. However this procedure is as well applicable for a modification to an in-service aircraft.

The operational cost data gathered from the field on in service aircraft are the "raw material" for most of the steps of this procedure. Without this feedback it is very difficult to ensure that this approach will result in real significant benefits for the operators.

The knowledge and collection of in service aircraft operational costs allows:

- To define a global operational cost objective for a new aircraft by comparison to the known position of other aircraft (Step 1).

- To split up this global objective from the experience of operational costs distribution on previous aircraft (Step 2).

- To identify the design requirements that would ensure that the objectives will be met (Step 3).

Without this feedback it is very difficult to ensure that this approach will result in real significant benefits for the operators.

STEP 1

The global DOC target has to be set and broken down to isolate the maintenance cost portion which is one of the areas where the aircraft manufacturer has the strongest impact.

STEP 2

Then from the new aircraft general characteristics and the experience of in service aircraft, an estimated baseline is issued and compared to the global operational cost target. If the estimated baseline is not matching the global target it may be indicating that the target is not achievable with the proposed general aircraft characteristics and that a review of these characteristics may be required. If both the baseline and the target are equivalent, we have a first breakdown of detailed objectives by ATA.
The method we use to estimate a baseline for a new design is based on parametric relations between operational costs and aircraft general characteristics. These relations were established from the data gathered on in-service. A relation has been defined for labor costs and for material costs for system and for the airframe based on a total of around 20 parameters for the whole aircraft. In the example shown on the bleed air system, operational costs are evaluated from a relation with the total thrust. The dots on the graph are plotting the operational costs of this system for different aircraft of different total thrust. In this case we have chosen a linear regression.

The predicted operational costs of any new aircraft may be estimated with this type of relations for every system and for the airframe. In order to control the impact of the flight length, the annual use, the sharing between on and off aircraft maintenance, the labor rate and efficiency, we are using adjustments factors that allow us to tune all costs to similar operational and environmental conditions.

The depth to which the global target must be broken down depends on the design activities and commercial work sharing.
For example:
- For system designers or global subcontractors, a breakdown to the ATA chapter level is acceptable.
- For equipment purchasers, a breakdown at equipment level for off aircraft work is expected.
- For maintenance engineering a breakdown by maintenance level is required.
- For program management a target by top cost drivers items is required.

STEP 3

This step is an engineering activity in close relation with the designer. The objective of this task is to translate the quantitative operational cost target into "words" (technical targets, commercial targets, design rules or recommendations) that are understood and applicable by the designers or the purchasers.

The technical targets are mainly linked to the interval to which a maintenance action will have to be performed and to the duration of the task. These targets may be on the mean time between unscheduled removals (MTBUR), the mean time between failures (MTBF), the mean time to repair (MTTR), the scheduled task interval, the BITE definition, the balance between the on-board maintenance system and the ground maintenance system.

The commercial targets are mainly related to the parts price and to the guarantee related to product support (DMC, spare price, MTBUR).

The requirements are related to accessibility of the items, maintenance test equipment and specific maintenance tools, level of repair, drainage, corrosion protection, repairability, interchangeability and standardization.

STEP 4

This step is the first one of the bottom-up approach: it starts from a design proposal and it consists in analyzing the associated reliability, maintenance and repair costs characteristics and evaluating the operational cost result. The maintainability analysis may also be conducted qualitatively in providing guidance to the designers to improve maintainability.

This step may also be conducted to compare two or many proposals to highlight the benefit of one solution compared to the others and initiate a trade-off on DOC to select the solution that will offer the greatest advantages. This trade-off may be performed for example between different concept maintenance, between different technical solutions or to optimize the balance between reliability and repair costs.

STEP 5

The last step of the procedure is a comparison of the estimated operational costs resulting from the maintainability analysis with the detailed targets. If the detailed objective at a lower level can not be reached, a decision to reallocate the objective at the next higher level may allow to match the global objective. The aim of this step is to monitor the objective consolidation process in order to ensure a clear follow-up of the achievements all along the aircraft development.

The first step of the procedure which is the settlement of a global target should be launched as soon as the project is launched as it is one of the high level program decision and that the challenge is to influence very up front the design decisions. The detailed target breakdown are derived from the global target and should be set prior to the selection of product concept. The maintainability design requirements are established from the detailed targets. As soon as a target is set, the associated requirements should be defined and we have considered that all requirements have to be set before the first metal cut. The maintainability analysis are linked to the design solutions and will start from the definition of the basic concept up to the end of the development. The objectives consolidation is linked to the results of the maintainability analysis and is in line with it on the milestone plan.

TOOLS AND ENVIRONMENT

This procedure is supported by many tools and methods and by a qualified staff. The in service experience is recorded in databases collecting data on operational interruptions, operational costs, reliability and pilots reports from the operators and/or from the suppliers. From this experience we have established operational costs baselines and an associated derivative method. We are recording all the supportability design requirements in a data base in order to record them for new programs. As for the contract we have harmonized in a standard format all the product support guarantees in order to better monitor the achieved results. An operational cost evaluation model was developed to perform analysis on proposed new design solutions. We are as well using level of a repair analysis model and a qualitative analysis model.

Most of our design office staff were trained to strengthen the customer oriented mindedness in their design tasks. We are working in teams integrating design engineers, purchasers, product support specialists, suppliers and customers. A concurrent engineering team is developing the tools to manage a program workflow linked to our CAD (computer aided design) system.

CONCLUSION

Direct operating costs are a major issue for operators in their purchasing decision and industrials must focus on this concern to remain competitive. The maintenance costs are a major contributor to operational costs and it has been demonstrated that design improvements can reduce maintenance costs. This can be performed during design by a formalized approach called "Design to operational cost". This procedure relies on the data on good and bad experience that operators are feeding back to the industrials. The results are to the benefit of the operators that will gain in profit margin and competitiveness.

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AIRCRAFT DESIGN TO OPERATIONAL COST

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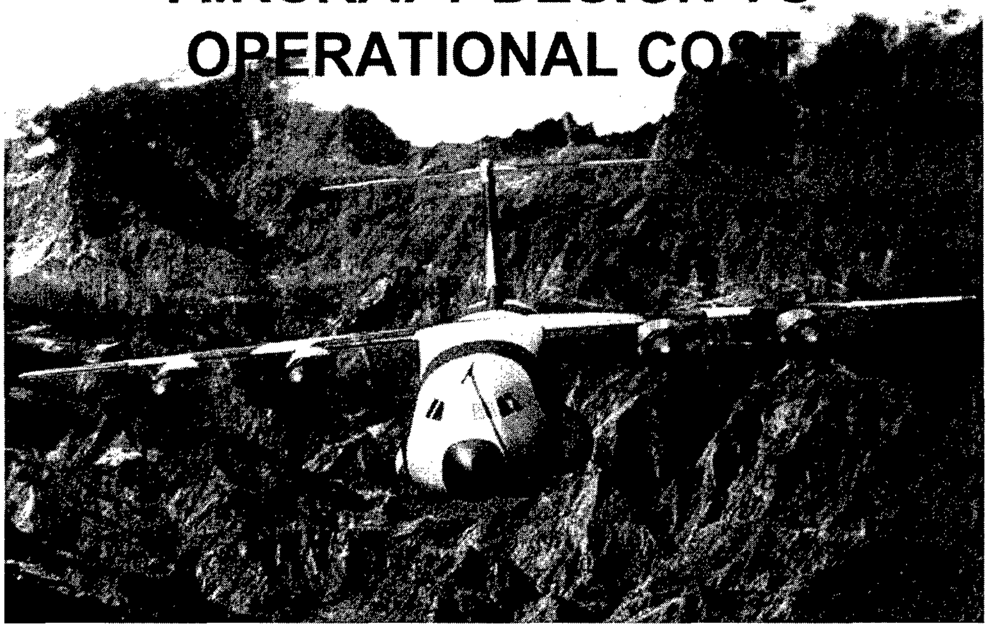

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CONTENT OF THE PRESENTATION

- 1. EVOLUTION OF OPERATORS EXPECTATIONS
- 2. DESIGN TO OPERATIONAL COST PROCESS
  - ¤ 2.1 Global target
  - ¤ 2.2 Detailed target breakdown
  - ¤ 2.3 Maintainability design requirements
  - ¤ 2.4 Maintainability analysis
  - ¤ 2.5 Objectives consolidation
- 3. TOOLS AND ENVIRONMENT
- 4. CONCLUSION

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AIRCRAFT DESIGN TO OPERATIONAL COST

1. EVOLUTION OF OPERATORS EXPECTATIONS

BEFORE

- HIGHEST SAFETY
- REQUIRED RANGE and CAPACITY
- LOW ENVIRONMENTAL IMPACT
- HIGH PASSENGER COMFORT
- HIGH DISPATCH RELIABILITY and MISSION RELIABILITY
- **LOW FUEL CONSUMPTION**

NOW

- HIGHEST SAFETY
- REQUIRED RANGE and CAPACITY
- LOW ENVIRONMENTAL IMPACT
- HIGH PASSENGER COMFORT
- HIGH DISPATCH RELIABILITY and MISSION RELIABILITY
- LOW OPERATIONAL COSTS

DIRECT OPERATING COSTS ARE A MAJOR ISSUE FOR OPERATORS IN THEIR PURCHASING DECISION

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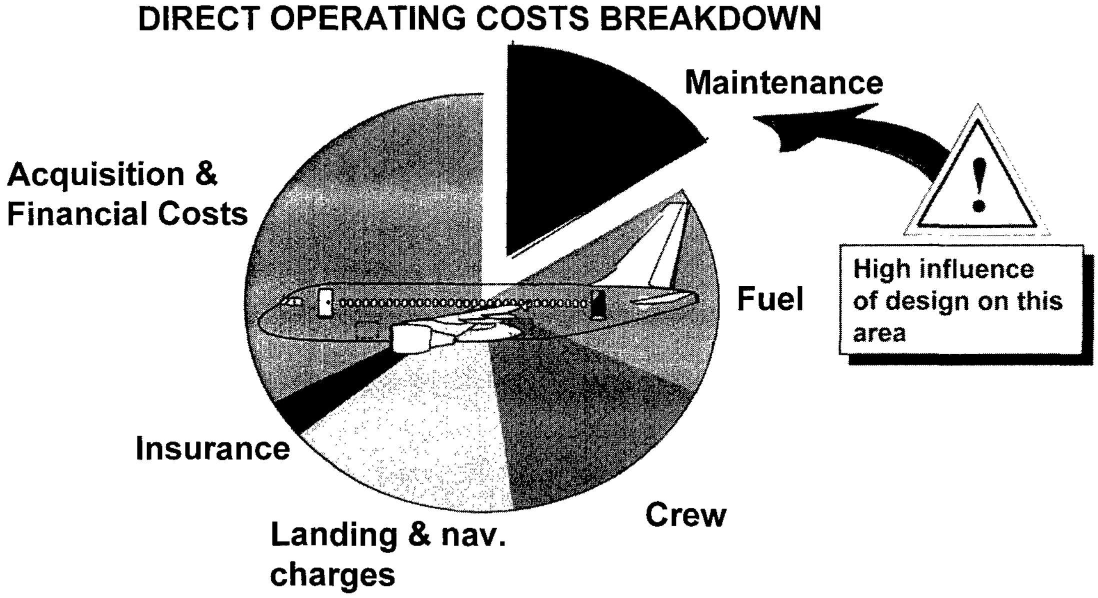
1. EVOLUTION OF OPERATORS EXPECTATIONS (Cont)

DIRECT OPERATING COSTS BREAKDOWN



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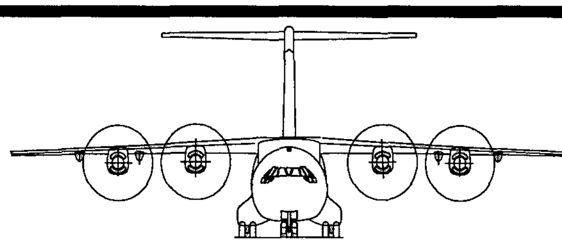
3. DESIGN TO OPERATIONAL COST PROCESS

CONTROL THE OPERATIONAL COST (and more specifically maintenance cost) BY INFLUENCING THE DESIGN TO REACH THE COST OBJECTIVE FOR THE OPERATORS



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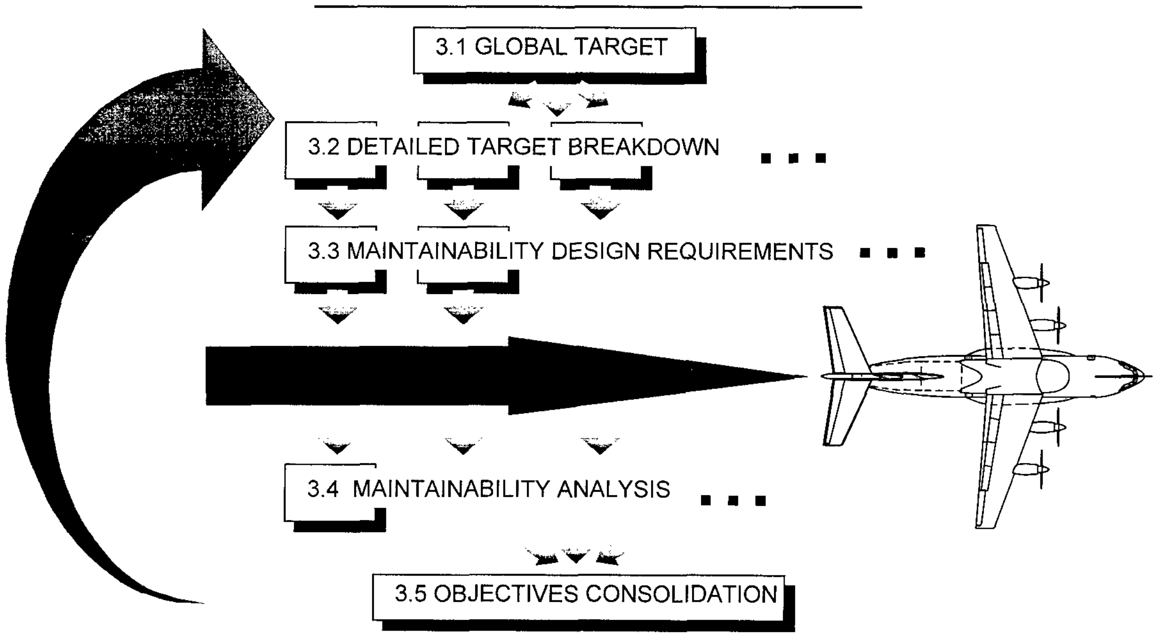
3. THE PROCESS STEPS



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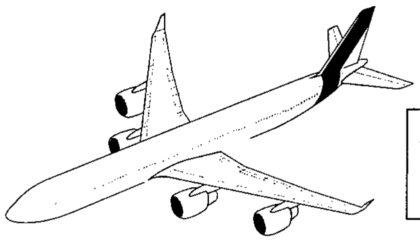
3.1 GLOBAL TARGET

Aircraft A: D.O.C. OBJECTIVE: -25% PER SEAT- MILE COMPARED TO Aircraft B



Aircraft A PROGRAM TARGETS:
- **TOTAL QUALITY (A/C & SUPPORT ELEMENTS)**
- **- 15% D.O.C. PER TRIP COMPARED TO PREVIOUS TYPE**

Aircraft A SUPPORT TARGETS: "MUST REQUIRED LESS THAN X MAINTENANCE MAN HOURS PER FLIGHT HOUR »

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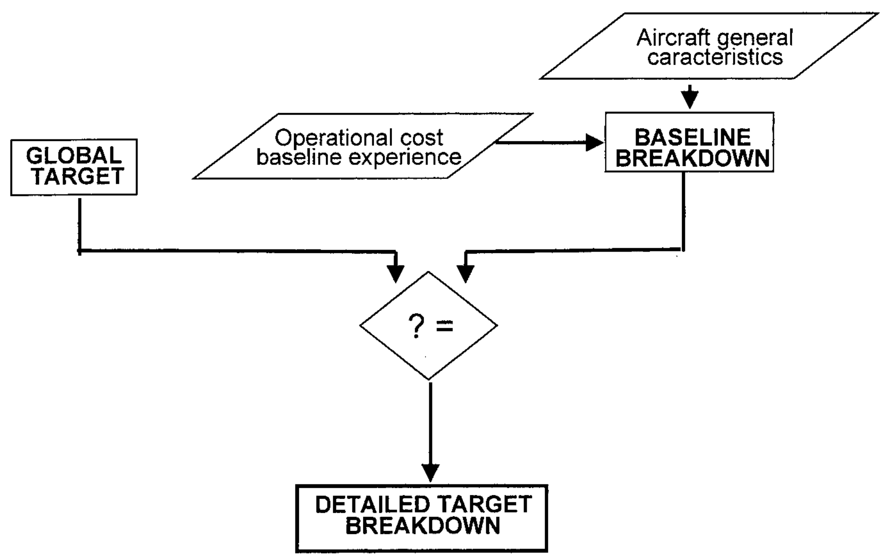
3.2 DETAILED TARGET BREAKDOWN



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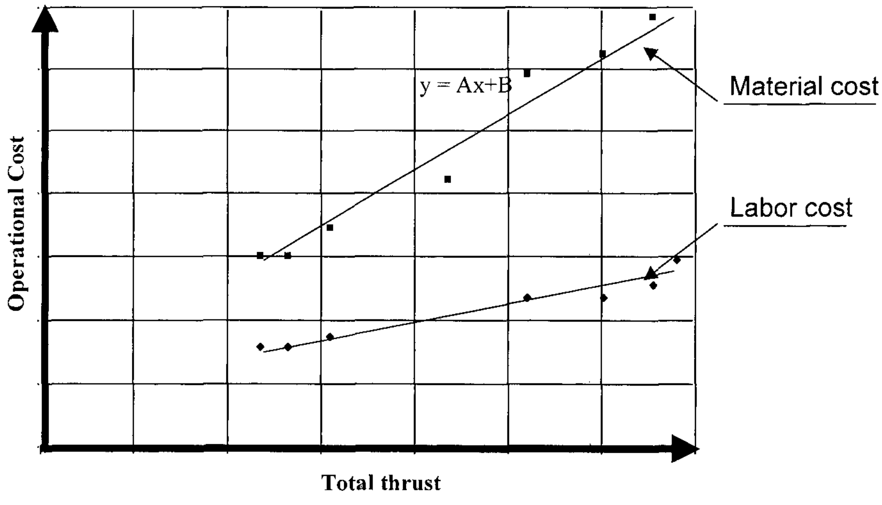
3.2 DETAILED TARGET BREAKDOWN (Cont)

Example of parametric approach: ATA 36 Bleed Air System



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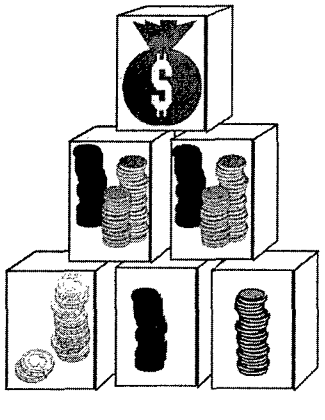
3.2 DETAILED TARGET BREAKDOWN (Cont)

Example of breakdown views for direct maintenance costs (DMC):



- DMC by ATA for labor, material
- DMC by maintenance level (A to C checks, higher checks, line...)
- DMC by manufacturer (industrial worksharing, GCP for vendors)
- DMC for cost drivers

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3.2 DETAILED TARGET BREAKDOWN (Cont)

BASELINE:

		LABOR			AT
ATA description	ATA	OnA/C%	Hourly%	Use%	AT
AIR CONDITIONNING	21				2
AUTO FLIGHT	22				2
COMMUNICATIONS	23				2
ELECTRICAL POWE	24				2
EQUIPMENT/FURNIS	25				2
FIRE PROTECTION	26				2
FLIGHT CONTROLS	27				2
FUEL	28				2
HYDRAULIC POWER	29				2
ICE/RAIN PROTECTI	30				3
INSTRUMENTS	31				3
LANDING GEAR	32				3
LIGHTS	33				3

DOC breakdown by ATA chapter

Average sector	X	FH
Annual util =	Y	FH
Labor rate =	Z	$
Labor Eff =	W	
Material usage :	V	

	BASELINE			BASELINE	
ATA	Labor	Mat.	ATA	Labor	Mat.
Line	$$	$$	52	$$	$$
21	$$	$$	53	$$	$$
22	$$	$$	54	$$	$$
23	$$	$$	55	$$	$$
24	$$	$$	56	$$	$$
25	$$	$$	57	$$	$$
26	$$	$$	71	$$	$$
27	$$	$$	72	$$	$$
28	$$	$$	73	$$	$$
29	$$	$$	74	$$	$$
30	$$	$$	75	$$	$$
31	$$	$$	76	$$	$$
32	$$	$$	77	$$	$$
33	$$	$$	78	$$	$$
34	$$	$$	79	$$	$$
35	$$	$$	80	$$	$$
36	$$	$$	36	$$	$$

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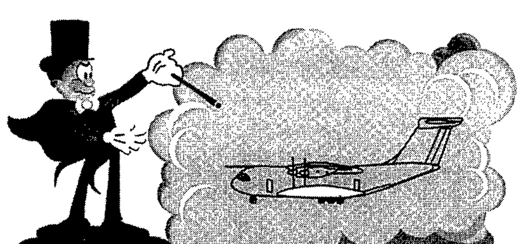
3.3 MAINTAINABILITY DESIGN REQUIREMENTS

- **Translation of the detailed cost targets into requirements applicable by the designers:**
  - Technical targets
  - Commercial targets
  - Design rules or recommendations



3.3 MAINTAINABILITY DESIGN REQUIREMENTS (Cont)

- Technical targets:
  - MTBUR, MTBF, MTTR, scheduled maintenance tasks interval, BITE performance, global performance of on board + ground maintenance system, ...
- Commercial targets:
  - DMC, spare prices, repair prices, ...
- Design rules or recommendations:
  - Accessibility, associated tools and test equipment, repairability, drainage, corrosion protection, interchangeability, standardisation, physical breakdown (repair level), ...

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AIRCRAFT DESIGN TO OPERATIONAL COST

3.4 MAINTAINABILITY ANALYSIS

- **Evaluation of maintainability / maintenance costs**
  - Bottom-up approach for operational cost evaluation from reliability, maintenance program and repair costs data
  - Maintainability qualitative analysis
- **Trade-off for design iterative decision process:**
  - Trade-off analysis for level of repair
  - Trade-off between different design solutions
  - Trade-off reliability vs repair costs
  - Support to designers / Installation analysis

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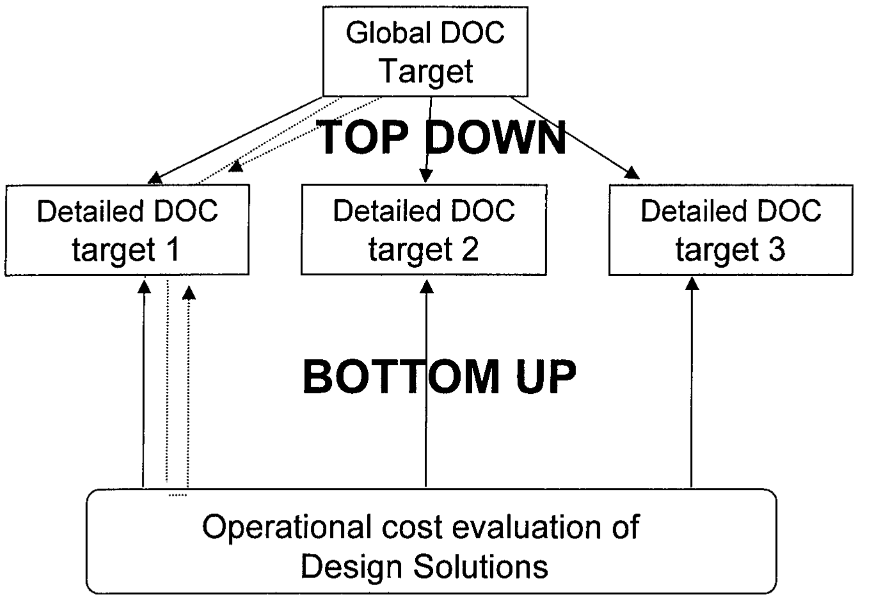
3.5 OBJECTIVE CONSOLIDATION



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4. TOOLS AND ENVIRONMENT

- In service experience database (Operational interruptions, Maintenance Costs, Reliability, Pilot reports)
- DMC Baselines
- Derivative method
- Design requirements database
- General conditions of purchase
- Operational cost evaluation model
- Level of repair analysis
- Qualitative maintainability analysis

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5. TOOLS AND ENVIRONMENT (Cont)

- Training / concurrent environment
  - Development of customer oriented behaviour by sensibilisation training of all staff on customer mindedness
  - Integrated teams: customers / design engineers / purchasers / product support / vendors
  - Concurrent engineering workflow

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6. CONCLUSION

- Aeronautical industries must focus on operational cost to remain competitive
- Design can have a major impact on maintenance cost which is a significant element of operational cost
- There has been success in reducing maintenance costs by a formalized consideration of them during the design phase
- Operators gain in competitiveness